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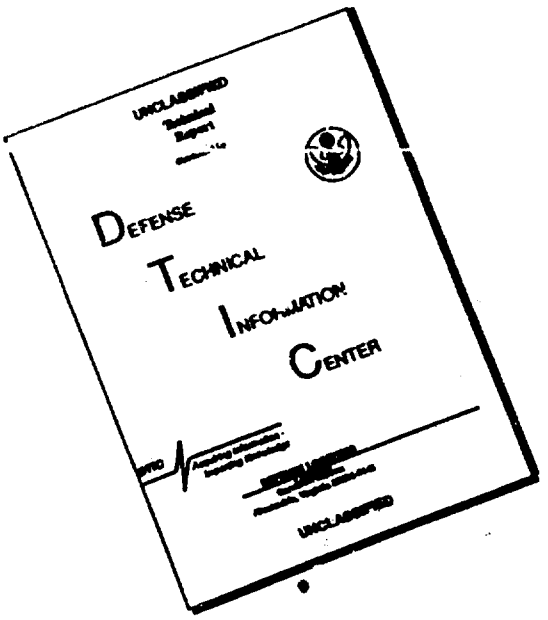

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DATA ON THE COMPARATIVE BIOCHEMISTRY OF HUMANS AND SIMIANS*)

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The biological proximity between simians and humans provides sufficient ground for the study of their biochemistry. However, the chemical statics and dynamics of simians have not been investigated very extensively, while other laboratory animals, such as the dog, rabbit, rat, etc., have been studied in much greater detail.

The comparative biochemical value of the scattered and meagre data on the biochemistry of simians is further reduced by the fact that corresponding data are rarely obtained as a result of simultaneous investigations and use of the same methods on both humans and simians.

Presented below are our laboratory data on the biochemical composition of the blood of simians, in comparison with corresponding data obtained from a blood analysis of healthy humans.

The investigation of lower monkeys was conducted on the species Macaca-rezus (two males and two females, 2½ to 3½ years old, weighing 2.7 to 4.1 kilograms). The blood was taken from the aural vein, after the animals had been subjected to a 16-hour starvation period.

In the comparative investigation of humans, venous blood was analyzed by the same investigation methods from a group of 10 healthy men and women, 19 to 25 years old.

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**) Assisted by A. K. Agayeva, O. V. Kekelidze, T. P. Pichkhaya and T. V. Pruidze.

In both cases, the blood was analyzed in order to determine the percentage of albumen fractions in blood (for this purpose, the method of electrophoresis on paper was used), quantities of glucoproteids, non-albuminous nitrogen compounds, lipides, mineral substances, the action of some ferments, and the quantities of various forms of adrenaline.(1)

The results obtained are shown in tables.

Table 1, shows the correlation of albumen fractions in the blood serum of simians and humans. For comparative purposes, data are also presented from Deutsch and Goodloe, (2) who employed the classical Tiselius method of electrophoresis.

Table I.

Quantities of Albumen Fractions in the Blood Serum of Humans and Simians

Object of Investigation	Number of Tests	Method of analysis	Quantities of albumen (in percentages) albumins	Alpha	Alpha	Alpha	Beta	Gamma	Gamma	Gamma	f 1)
Humans	10	Electrophoresis on paper	64.3	5.4	6.6	—	9.7	-	13.8	-	
	3	Deutsch and Goodloe calculations (Tiselius method	59.6	6.7	8.6	—	11.0	4.8	6.1		
Monkey (Macaco-)	4	Electrophoresis on paper	61.2	3.8	3.4	—	11.9	-	19.6		
	3	Deutsch and Goodloe calculations Tiselius method	50.0	5.9	5.2	4.7	16.1	8.4	9.1	0.5	

1) f-fractions preceding albumins, the nature of which is unknown.

In analyzing the data on the determination of protein fractions as shown in Table 1, we must realize that for obvious reasons we can not expect an exact coincidence between the results obtained by the method of electrophoresis on paper and the results obtained by the Tiselius method. Therefore, the comparison of the results of the two methods can not be complete. In spite of this some comparison of the data is possible. As seen from the table, both methods of analysis yield comparable results. The electrophoresis on paper gives higher values for results on the quantity of albumen and comparatively low values for results on the quantity of globulins. This is even more clearly reflected in the results of the analysis of blood serum in simians.

We were interested in the question whether the albumen fractions in the blood of simians possess characteristics which could be considered specific to their species. A certain amount of evidence for such a conclusion can be found in our data. It may suffice to point out that the percentage content of the alpha and alpha - globulins is considerably lower in the blood of simians than in the blood of humans, while the content of gamma-globulins is slightly higher in the blood of simians than in human blood. It must also be noted that in respect to gamma-globulins, these differences are less pronounced. As it is known, the number of gamma-globulins which basically carry different anti-bodies sharply increases in immunized animals. At the present time gamma-globulins are widely used as preventive and curative means in combating many infectious diseases (the protection of monkeys from experimental poliumyelitis by the use of gamma-globulins of human blood can be cited as an example).

According to the data of Deutsch and Goodloe, the percentage content of gamma-globulin in the blood plasma of both humans and simians (Macacorezus) is the same. These authors found the difference between the blood plasma of humans and simians in the quantity of the first electrophoreous fraction (f) which precedes the albumins (origin of this fraction has not been determined), and also in the presence of alpha-globulin fractions, which are also found in the blood of cats and guinea pigs. As can be seen from the data of these authors, the quantitative differences are of a less pronounced nature.

On the basis of the above-mentioned differences, we can conlude that the electrophoretic characteristics of the blood of lower monkeys provide us with sufficient evidence for the determination of specific distinctions between these animals and man.

Table II.

Quantities of glucoproteids in milligram percentage in the blood serum of healthy humans and simians

Object of investigation	Number of tests	Limits of variations in mg %*)			
		Hexose, related to albumen	Hexosamine related to albumen	Neiram acid	Seromucoid (Mucoproteins) in the form of Hexose
Man	10	104-143	78-106	56-71	9-15
Monkey (Macaco-Rezus)	4	92-109	65-91	83-88	16-25

*) milligram percent, henceforth referred to as mg %

In relation to simians, the data are only of a tentative character. Nevertheless, they give us reasons to suppose that the deeper study of glucoproteids in the blood of simians (not only in lower monkeys, but also in anthropoid apes) can be of substantial interest to comparative biochemistry.

As far as non-albuminous nitrous substances are concerned, comparative data are presented in Table 3.

Table III.

Quantities of non-albuminous nitrous substances in the blood serum of humans and simians

Object of investigation	Number of tests	Urea mg% of nitrogen	Creatinine, mg% of nitrogen	Uric acid, mg% of nitrogen	Amino acids, mg% of nitrogen	Glutathione, reduced, mg%	Ergotioneine, (Ergotinine ?) mg%
Man	10	10.2-15.3	0.45-0.72	0.75-1.8	5.8-7.9	21.0-28.5	2.1-3.8
Monkey (Macacarezus)	4	9.4-1.4	1.2-2.1	0.32-0.65	6.1-8.1	8.0-18.0	0.0

The above presented data allow us to see considerable differences in the distribution of non-albuminous nitrous substances in the blood of humans and lower monkeys (a higher concentration of creatinine, a lower concentration of uric acid and glutathione, and the absence of ergotioneine is found in the blood of monkeys).

It is necessary to point out that lower monkeys secrete very little uric acid as such. They transmute the uric acid into allantoin, which is charucteristic of a majority of mammals, with the exception of anthropoid apes and man himself. This fact can be compared to the above-cited data on the low level of uric acid in the blood of lower monkeys. In spite of the fact that allantoin may be found in small quantities in the urine of humans (urine of newborn babies contains a considerable amount of allantoin), this biochemical peculiarity of the urine of lower monkeys is of interest.

It is possible that anthropoid apes (as well as humans) are deprived of the ferment of uricase, under whose influence uric acid turns into allantoin.

In as far as the quantity of non-albuminous nitrous substances in the whole blood of lower monkeys is concerned, only those data are available (3) which show that the quantity of urea varies within the limits of 5.8 - 6.4 mg%, the quantity of uric acid, within the limits of 0.3 - 0.4 mg%; and the quantity of creatinine is 1.4 mg% (all data are given in mg% of nitrogen). (See Table 3).

The content of lipides in the fluids and tissues of simians is very little known. According to the data of N. I. Tavastsherna (4), the whole-blood of monkey-rezus contains 167 mg% of common chloresterine, and that of monkey-lapunder contains from 120 - 149 mg%. In the blood serum of a young female (three years old), N. I. Tavastsherna found 105-118 mg% of common chloresterine, in the blood of a young male, 118 mg%, and in the blood of an old male and female, 100 and 177 mg%, respectively. According to other data (5) the blood serum of a monkey contains 118 mg% of common chloresterine.

Our laboratory has obtained only a few results from the blood analyses of lower monkeys (rezus). These results offer some idea on the distribution of free chloresterine and its ethers in the blood of simians. According to these results, the whole-blood of a monkey contains 115-132 mg% of common chloresterine, 22-31 mg% of ether-related chloresterine.

As we know, numerous investigators give contradictory data on the quantity of chloresterin in the blood (serum, plasma) of humans. Especially contradictory are the data on the extreme content ranges of chloresterine. 150-200 mg% of common chloresterine are accepted as the standard rate for whole-blood. (6)

In spite of the meagre data, it appears that the blood of simians contains a slightly smaller amount of common chloresterine than the blood of humans. The low percentage of free chloresterine (about 20 percent of the total amount, instead of 30 - 40 percent usual for the blood of mature men in the blood of simians, resembles a picture often observed in the blood of children.

The data on the quantity of chloresterine in the blood of simians also resembles the blood of humans under starvation. In the blood of humans under starvation, together with the reduced quantity of chloresterine, a reduced level of albumen is also observed.

In the blood of both simians and humans, the quantities of calcium, iron, copper, zinc, silicium, iodine, and various forms of sulphur were determined.

Data characterizing the quantities of these mineral substances in the blood of humans and simians are shown in Table 4.

Table IV

Quantities of mineral substances in the blood of lower monkeys and humans:

(Authors' data and data taken from other sources)

Mineral substance	Type of monkey	Whole blood: Monkey	Whole blood: Man	Plasma or blood serum: Monkey	Plasma or blood serum: Man	Red Corpuscles: Monkey	Red Corpuscles: Man	Source
Calcium in mg%	Macaca rezus	9.1-13.2	9.1-11.0	—	—	—	—	Authors' Laboratory
Magnium in milliequiv. per 1000 ml*)	"	4.1-4.8	3.0-3.7	2.1-2.7	1.7-1.9	5.8-5.9	1.6-6.7	Albritton (?)
Iron in mg%	"	38-48	49-56	—	—	—	—	Authors' Laboratory
Copper in mkg% **)	"	69-85	77-106	--	—	49-77	32-111	"
Zinc in mg%	"	"	"	0.36	0.21	0.92	0.144	"
Silicium in mg%	"	5-64	49-56	20-36	15-26	—	—	"

(* milliliteres, ** milliklograms (?), henceforth referred to as ml and mkg, respectively).

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Mineral substance	Type of monkey	Whole Blood: Monkey	Whole Blood: Man	Plasma or blood serum: Monkey	Plasma or blood serum: Man	Red Corpuscles: Monkey	Red Corpuscles: Man	Source
Chlorine	Cebus capuchin	—	—	110.2-122.8				Britton (8)
	Aotus-zonalis	—	—	99.6-117.2	95.0-110.0	—	—	
	Leontocebus zhofr.(?)	—	—	113.2-120.6				
Iodine	Macaca rezus	4.9-7.1	6.0-8.5	—	—	—	—	authors' Laboratory
Phosphorus 1) inorganic	"	3.6	3.6	—	—	—	—	Rapaport & Guest (9)
2) organic, acid-soluble	"	21.8	23.1	—	—	51	41.6	
Adenosine triphosphate-acid (ATP)	"	5.0	8.1	—	—	12.0	18.2	

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Mineral substance	Type of monkey	Whole Blood		Plasma or blood serum		Red Corpuscles		Source
		Monkey	Man	Monkey	Man	Monkey	Man	
Diphosphorglyverinoacid	Macaca rezus	13.0	12.4	—	—	31.0	29.0	
Sulphur in mg%								
1) inorganic	"	—	—	4.8-6.2	2.8	—	—	
2) organic	"	—	—	1.4-2.3	1.9	—	—	
3) general oxidized	"	—	—	4.3-7.1	5.8	—	—	
4) non albuminous	"	—	—	5.6-8.1	7.7	—	—	Authors' Laboratory

Note: Albritton (7) gives the contents of chlorides in milliequivalents to 1000 ml of the blood of simians: whole blood: 83-110 (average - 93); plasma: 103-118 (average-110); erythrocytes: 56-73 (average - 67).

The table also includes data obtained by various investigators at different times but employing the same method of blood analysis on both humans and simians.

As can be seen from Table 4, data on the mineral composition of blood show no special distinctions between the blood of lower monkeys and humans. Hence we can reach the conclusion that the formulae of liquids which can compensate the loss of blood when they are injected into blood vessels can be first determined on lower monkeys and later applied to human beings.

Unfortunately, data on the individual components of the salt-composition of the blood of simians were obtained by different investigators (including authors of this article) during various seasons of the year. It is therefore impossible to determine the presence of probable seasonal fluctuations in the data.

At the same time, in spite of all the similarity of mineral compositions, the erythrocytes /red blood corpuscles/ of humans are slightly richer in zinc content.

This does not completely correspond to the degree of activity of carbonic anhydrosis /ugol'naya angidraza/ (of which zinc is a constituent part), which is the same in the blood of humans and simians.

The somewhat higher quantity of magnesium found in the whole-blood of simians is probably due to the fact that the investigations were conducted on young monkeys (the erythrocytes of young animals are usually richer in magnesium). The slightly lower quantity of iron and copper found in the whole-blood of simians, corresponds to the lower concentration of common albumen (particularly hemoglobin) in the blood of simians, which was mentioned earlier.

It is a known fact (10) that the average quantity of hemoglobin is slightly lower in the whole-blood of simians than in the whole-blood of humans.

It is of interest to comparative biochemistry that the simians and humans belong to the same group of mammals, i. e. if we judge them on the character of the selective concentration of potassium ions by erythrocytes. In the second group of mammals, we would then have the dog and the cat, which have a predominance of sodium in the erythrocytes in their blood.

In respect to specific albumen-ferments, corresponding data are rather scanty. A. S. Konikova and A. V. Vodova (11) discovered that the catalytic activity in the blood of the baboon-hamadril /gamadril/ con-

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stitues 6.75 equivalent units (according to the method of A. N. Baon abd Zubkova), while the proteolytic activity in the blood of three baboon-hamadrils, equalled 20, 23, and 29 mg% of residual nitrogen. This figure is noticeably higher than the figures obtained from the analyses of normal blood.

According to the data of these investigators, the amylase activity in the blood of three lower monkeys equalled 12.0, 22.6 and 41.1 mg% of sugar . Corresponding analyses of human blood were not performed.

Finally, the review of H. Gibian (12), mentions the presence of a considerable quantity of carbonic anhydrosis in the cerebellum and cortex of a monkey (type not indicated). According to C. Kochakian and others (13), the blood of lower monkeys, unlike the blood of man, does not contain any arginases. The lower monkeys also differ from humans and anthropoid apes in the fact that their blood contains ferments of uricase. In the available literature, we did not find any other information pertaining to the blood ferments (enzymes?) of simians.

Data which were obtained in our laboratory are presented in Table 5.

Table V

The activity of various ferments in the blood of humans and simians:

Object of investigation	No. of tests	Ferments (in equivalent units)			
		Amylase after King	Aldolase after Brun	Alkaline Phosphatase after Bodanski	Carbonic anhydrase after Brinkman-Kreps
Man	10	85-195	3.3-8.0	1.6-4.8	2.3-2.8
Monkey (Macaca-rezus)	4	65-220	2.6-14.5	2.5-16.5	2.4-2.9

An analysis of this data shows an extensive range of variations of the amylase activity in the blood serum of simians. Those variations in the titre of amylase were observed not only in different monkeys. For instance during a period of 15 days we found that the variations in the amylase activity of the blood serum of the very same monkey ranged from 80 to 170 equivalent units.

If we supplement those facts by the findings of S. D. Balakhovskiy (14), who points out that the variations in the titre of amilase in the blood of healthy humans, are not extensive, we can speak about specific distinctions of lower monkeys. However, observations of healthy humans show (see Table 5) that similar variations in the titre of amilase are also possible in the human blood.

We were also unable to find any special differences between the aldolase activity in the blood serum of lower monkeys and that of healthy humans. More evident are the differences in the phosphatase activity. The quantity of alkaline phosphatase in the blood serum of the rhesus monkey considerably differs from the quantity of the same agent in the blood serum of grown men and somewhat resembles the variations of the titre of alkaline phosphates in the blood of younger children. However, we can not entirely exclude the possible presence of obliterated, beginning stages of rachitis, in the captive monkeys under investigation. As it is known, rachitis is followed by an increase in the titre of the phosphatase in the blood.

It was also indicated that the amount of carbonic anydrase in the blood of the rhesus monkey and in the blood of humans are almost the same.

Data on the quantity of hormones in the blood of simians, particularly hormones which are secreted by the adrenal glands, are also of considerable interest to comparative biochemistry.

The quantity of corticosterone /"Kortikosteron"/ and hydrocortizone /"Gidrokortizon"/ (that is, 17-oxicorticosterone /"17-oksikortikosteron"/) in the blood flowing from the adrenal glands gives us a basic idea about the secretory activity of these glands. The activity of the glands in simians, is of a different character from that in humans and other kinds of animals. We have some data which show that the quantity of 17-corticosterone in simians is 20 times higher than the quantity of corticosterone. As far as cortizone is concerned, it can be found in the peripheral blood and urine of humans but not in the blood flowing from the adrenal glands.

The quantity of 17-oxisteroids /"oksisteroid"/ in the blood of lower monkeys was recently determined in reliable investigations (16). The investigations were carried out on 50 monkeys of the Macaca-rhesus and Cinomolgus /"tsinomolgus"/ species. In respect to the quantity of steroids in the plasma of peripheral blood, the authors found no differences between the kinds /species/ and sexes.

The average level of 17-oxisteroids was 37.7 mg% (standard deviation of 7.8). By comparing this data with corresponding data on human blood (6), we find that the blood of the rhesus monkey contains almost three

times more steroids than the blood of humans. This picture of adrenal steroids gives us a basis for the assumption of specific distinctions in the biochemistry of lower monkeys.

We found no data in the literature about another hormone of the adrenal glands - the adrenaline - nor did we find anything about adrenalinemia in simians. The activity of the cerebral layer of adrenal glands is of interest, even if only because of the fact that during the deficiency of adrenals, the biochemical peculiarity of the carbo-hydrate metabolism in monkeys is characterized by an appreciable low level of sugar in the blood, and glycogen in the liver. This fact stands in a contrast to the comparatively high values of the conclusive data (17). The chief symptom of this deficiency in simians, are hypoglycemic convulsions. As far as the level of glycogen in the muscles and in the heart is concerned, lower monkeys hardly differ from humans.

Our laboratory has at its disposal a number of results from the analyses of whole-blood of the rhesus monkey. The quantity of adrenaline varies between 0-35 mkg% and the quantity of dehydrenaline, between 0-18 mkg%.

As it is known, data on the quantity of adrenaline in the blood of humans are quite contradictory, as they vary with the methods of analysis used by the various researchers. For this reason, we shall compare only the results of those researchers who used the same methods of analysis. T. P. Pichkhaya (18), found that the fluctuations of adrenaline in the blood of humans remain within the limits of 8-28 mkg%, and the fluctuations of dehydroadrenaline, within the limits of 2-25 mkg%.

A comparison of the titres of physiological adrenalinemia and hyperadrenalinemia shows a close similarity in this aspect between the biochemistry of humans and simians.

Conclusion

On the basis of the above-presented information, we can conclude that the intensified study of biochemical indices of the organisms of lower and higher monkeys is of considerable interest and should, undoubtedly, yield materials for a further differentiation of biochemistry (possibly, not only between species but within species as well). The application of the methods of biochemical analysis, as used in the study of the biochemistry of humans, to the systematic study of simians, should produce information which can be of considerable interest for the understanding of the evolution of biochemical processes. The application of the biochemical analysis will also enable us to use monkeys as objects for the experimental reproduction and study of those diseases which are common to man.

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